

Optimal Exploitation of 3D Electro-Optic Identification Sensors for Mine Countermeasures

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LONG-TERM GOALS

The overall goal of this project is to utilize existing hardware and model assets to address issues critical to the operational deployment of advanced electro-optic identification (EOID) mine countermeasure (MCM) sensors. EO identification of mines is specified as a requirement for the next generation of Navy MCM systems (e.g., AQS-20(A) and RMS). With maturing sensor technology, like the Areté developed Streak Tube Imaging Lidar (STIL), transitioning to the fleet, this effort has been undertaken to evaluate optimal STIL performance, predict STIL performance with advanced imaging models, and to make these EO sensor modeling tools and predictions available.

OBJECTIVES

This two-year collaborative effort, including teams from Areté Associates, Coastal Systems Station (NAVSEA/CSS), Metron, Inc., Raytheon, and Northrop Grumman, has utilized existing sensors and sensor models to address issues critical to the operational deployment of subsurface EOID sensors. Under this task, Areté has integrated and fielded an existing STIL sensor for at-sea experimental collections. STIL data sets were analyzed and compared extensively with modeled results for a significant number of targets, backgrounds, and operationally relevant environmental conditions.

APPROACH

The Streak-Tube Imaging Lidar (STIL) is a compact, high-resolution, 3-D imaging sensor with no moving parts. It uses a blue-green pulsed laser transmitter with a fixed cylindrical lens to project a fan beam beneath the sensor vehicle onto the ocean bottom. Conventional imaging optics are used to image the illuminated area onto a slit photo cathode of the streak tube. Electrons released from the photo cathode are accelerated and electrostatically swept onto a phosphor anode, forming a 2-D range/azimuth image for each laser firing. Two conventional CCD cameras then produce digital range/azimuth imagery. Volumetric image data is created with along-track sampling performed in a

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push broom fashion by utilizing vehicle motion and successive laser firings. The resulting raw 3D image data is then processed to produce conventional contrast maps of the bottom and targets, as well as range maps which represent the height of objects above the surrounding background of the sea bottom.

During FY01 the Areté-developed AQS-20 prototype STIL sensor was retrofitted and integrated into a larger tow body (shown in Figure 1) along with two additional laser line scanner EO sensors for data collections. The collected data has served as a baseline for FY02 modeling efforts, which focused on specific enhancements to previously developed STIL performance and imaging models, and overall validation of these models.



Figure 1: STIL, Processing System, and EOID Multi-sensor Tow Body
[Tow body shown dockside with STIL sensor integrated in small section ahead of the tow body wing. STIL CAD drawing. STIL Sensor in Laboratory. Topsides processing system as deployed onboard ship]

WORK COMPLETED

After laboratory testing and integration of the STIL sensor into the larger tow body, numerous at-sea data collections were conducted. These tests included a variety of standoff ranges, environmental conditions, and operational scenarios. Tests were conducted aboard the R/V *Mr. Offshore* off Panama City, Florida. In all, over 155 Gigabytes of raw STIL data was collected containing signatures of various technical targets, mine-like objects, and clutter. After processing and analysis of these data sets, work began on generating initial modeled test cases for direct comparison. Based on these initial results, several enhancements were made to the Areté STIL model to better predict system performance and improve image quality. Once these improvements were completed, the task of making model runs for each of the key target scenarios and operational and environmental conditions were undertaken. Each data set was then compared to the actual data for model validation purposes using various metrics defined by the EOID team.

RESULTS

Shown in Figure 2 is a sample of STIL EOID contrast (or intensity) imagery from the sensor (left) and a corresponding modeled image (right) over a field of complex technical targets used during the FY01 at-sea collections. The technical targets contain 3-D cones, cylinders, hemispheres, boxes, and other complex 3-D shapes. Note how the model simulates the incident angle dependent contrast return on the hemispheres and cones in the upper portion of the figures. Similarly, examples of real and modeled STIL range data are shown in Figure 3.

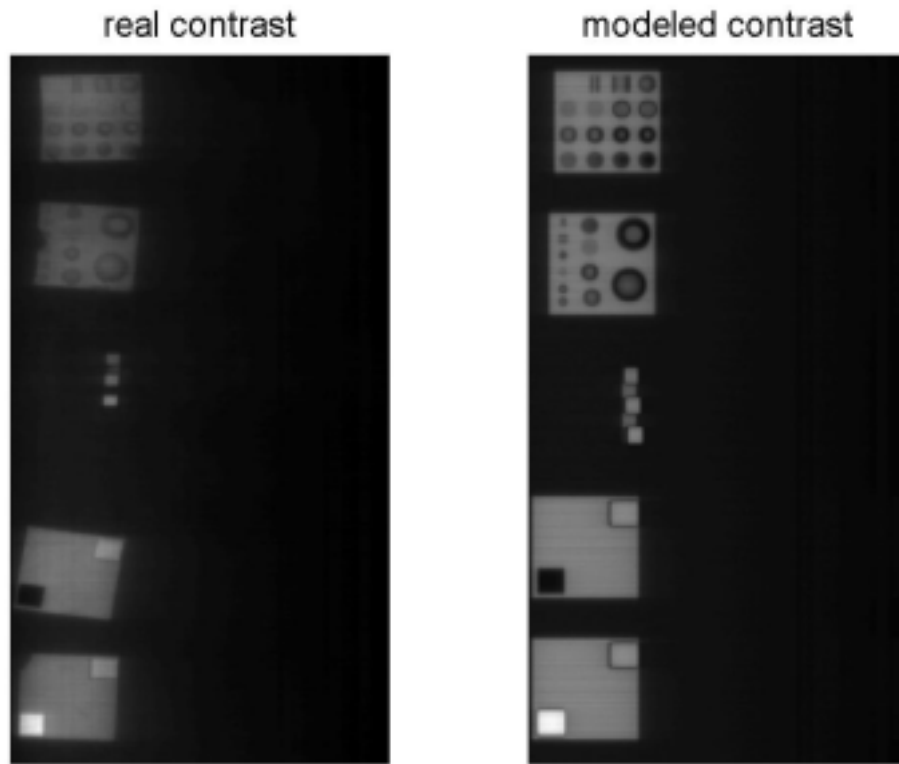


Figure 2: STIL Contrast Images [actual EOID sensor image on left, modeled STIL intensity image on right, both images depict the same technical targets]

Figure 4 shows cross-track contrast profiles of real and modeled STIL image data, which characterizes the radiometry of the modeled signals. These types of comparisons, and many others, serve to determine the overall performance of the modeled data against the real data. In this figure, the corresponding target was a flat, uniform high reflectance panel and the sensor was at a relatively high altitude. The two target return profiles are nearly identical, with the exception of random noise variations. The roll-off in signal level as a function of increased slant range and incidence angle is also very similar. The offset between the real and modeled bottom returns shown in the data is due to differences in the reflectance estimates of the bottom. Note also that the cross-track contrast variation, or noise, appears to possess the same statistical characteristics for the real and modeled images.

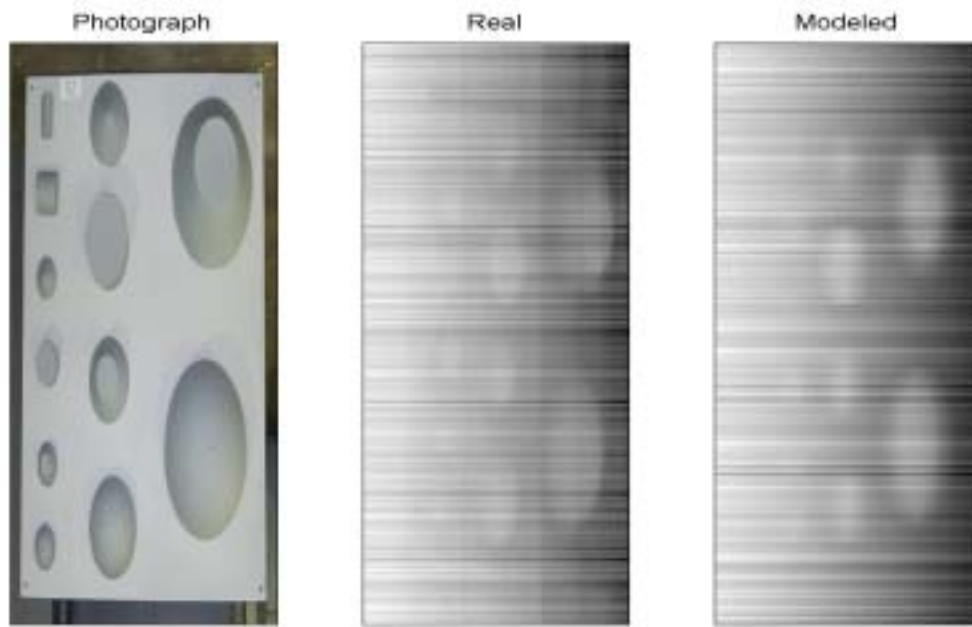


Figure 3: Range Capability [Photo of technical target, STIL range images from the EOIDS sensor, modeled STIL range image showing same technical target]

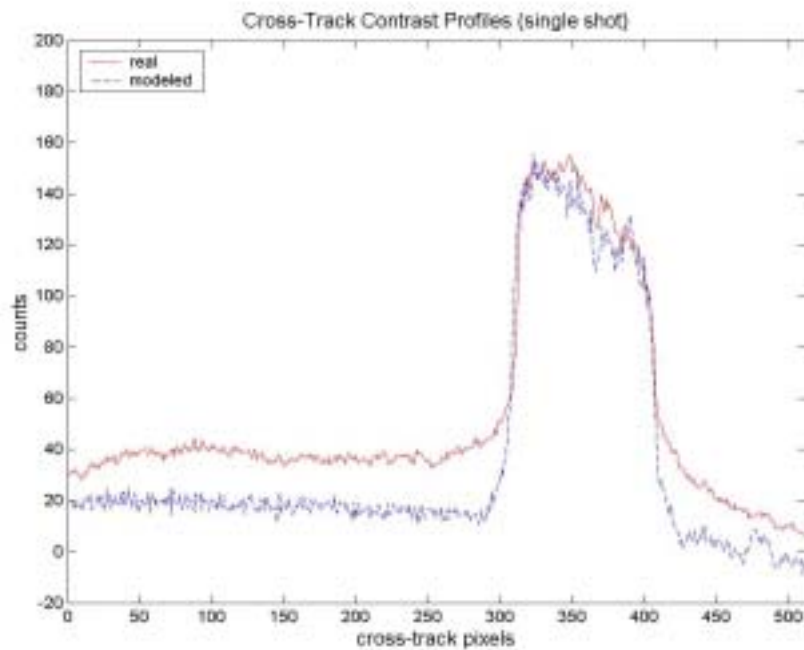


Figure 4: Cross-Track Contrast Profiles of Real and Modeled data [graph: curves show very similar structure and agreement]

The Areté STIL modeling suite has undergone substantial testing and initial validation using data collected during at-sea tests under various scenarios and conditions. Results of this validation have been very promising to date. Furthermore, lab calibrations and characterizations of the EOIDS STIL system have allowed the model to be fine tuned to provide for very realistic simulated imagery, both in

contrast and range. And with the addition of the graphical user interface (GUI), the Areté STIL model suite becomes a very effective and useful tool for many underwater EOID imaging applications.

IMPACT/APPLICATIONS

The exploitation of high-resolution 3D imaging will have a significant impact on the ability to positively identify mines, reduce the likelihood of false target identification, and will result in appreciable improvements in MCM clearance effectiveness. The STIL EOID sensor allows rapid mine identification at various speeds and standoff ranges. This broad operational envelope will provide extended utility over a wide range of environmental conditions. Validated STIL performance and imaging models will enhance the ability to effectively use this new sensor asset.

TRANSITIONS

As a result of the successful integration and testing of the STIL EOID sensor, this technology was selected for integration into the underwater AQS-20(A) system and a STIL variation was selected for the Airborne Laser Mine Detection System (AN/AES-1). Two Engineering Development Model systems for the AQS-20(A) are currently undergoing final integration and acceptance testing under NAVSEA contract N00024-99-C-6337. Three Engineering Development Model systems for the AN/AES-1 are being developed and tested under NAVSEA contract N61331-99-R-0022.

Several organizations have requested and received STIL sensor data and processing code during this contract. These recipients of data and algorithms are listed in Table 1.

Table 1: STIL Data Transfers during FY01-FY02

STIL Data Type	Year	Data Description	Receiving Organization	Point of Contact
Raw sensor Data	2000	Data collected in the Gulf of Mexico	NAVSEA/CSS	Andy Nevis
Full Frame data	2000	Data collected in the Gulf of Mexico	NAVSEA/CSS	Michael Strand
Raw sensor Data and Processed Data	2001	Data from first multi-sensor experiment in the Gulf of Mexico	NAVSEA/CSS	Mary Hulan
Raw sensor Data	2001	Data from System health checkout in Gulf of Mexico	NAVSEA/CSS	Andy Nevis
STIL Processing Algorithm code	2002	Code for processing STIL data	NAVSEA/CSS, Metron, Inc.	Andy Nevis, Tom Stefanick
Raw and Processed Data	2000-2002	Various data sets to work with in on-going modeling effort	Metron, Inc., NAVSEA/CSS	Tom Stefanick Andy Nevis

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PUBLICATIONS

“Assessment of Streak Tube Imaging Lidar (STIL) Sensor Performance and Imaging Model,” Holmes, V.T.; Hilton, R.J.; Couch, L.J.; Ocean Optics XVI; November 18-22, 2002, Santa Fe, NM.